Europäisches   European Patent   Öffice européen
Patentamt   Office   des. brevets

Bescheinigung   Certificate   Attestation

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten Internationalen Patentanmeldung überein.

The attached documents are exact copies of the International patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet international spécifiée à la page suivante.

Den Haag, den
The Hague,
La Haye, le   1 5 MAR 2005

Der Präsident des Europäischen Patentamts
Im Auftrag
For the President of the European Patent Office
Le Président de l'Office européen des brevets
p.o.

C. v.d. Aa-Jansen

Patentanmeldung Nr.
Patent application no.   PCT/EP 04/051317
Demande de brevet n°

Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

Anmeldung Nr.:
Application no.:
Demande n°:

PCT/EP 04/051317

Anmelder:
Applicant(s):
Demandeur(s):

1. SWISS REINSURANCE COMPANY - Zürich, Switzerland
2. FEYEN, Hans - Zürich, Switzerland (US only)
3. MEHLHORN, Jens - Zürich, Switzerland (US only)

Bezeichnung der Erfindung:
Title of the invention: Method and system for Automated Location-dependent Recognition of Flood Risks
Titre de l'invention:

Anmeldetag:
Date of filing:
Date de dépôt:

30 June 2004 (30.06.2004)

In Anspruch genommene Priorität(en)
Priority(ies) claimed
Priorité(s) revendiquée(s)

Staat: State: Pays:	Tag: Date: Date:	Aktenzeichen: File no. Numéro de dépôt:

Bemerkungen:
Remarks:
Remarques:

Further applicants:

4. OEHY, Christoph - Zürich, Switzerland (US only)

Method and System for Automated Location-dependent Recognition of Flood Risks

This invention relates to a method and system for automated location-dependent recognition of flood risks, flood states being measured and
5   location-dependent probability values being determined. In particular, the invention relates to a system and a method where a country-specific flood zone table, such as e.g. the First American 100-year flood zone table, is used to derive high resolution data on vulnerability factors for generalized insurance risk factors.

10   Today an appropriate automated flood rating system is painfully lacking. For many countries, it is hardly possible to do a technically correct flood rating. A glance at the loss history shows that economic losses caused by flood are eaqually high or higher than those of earthquakes, windstorms other perils. For most of these other perils mostly exist already various rating and
15   prediction systems. High amounts of money, industrial power and time are lost by flood events. Additionally, with the trend of increasing insurance penetration for floods, the insurance and re-insurance industry is affected ever more by flood losses. To extend the flood rating to detailed and even facultative business, however, the threat of immense data amounts has to be coped with.
20   This is done by completely new concepts on the hazard event set as well as on the system and/or method side.

      One of the objects of the invention is to provide a new approach to creating a stochastic event set. The main benefit of the new approach has to be the economic use of storage, which also positively influences the performance
25   of the rating. Instead of storing water depths for each of the tens of thousands of events, e.g. only a flood frequency map or something similar should be stored at a highly detailed level (90m resolution). The event return periods should be generable and storable on an aggregated high-resolution grid level for the territory.

30   It is well known that floods cause equally high or higher economic losses than storm or earthquakes. Considering losses on industrial books, flood

losses typically exceed by far earthquake or storm losses. Figure 1 shows in the observation period 1 January1997 - 31 December 2000, that flood accounts for 55% of all natural peril-induced damage to property corporate business and for 44% of all natural peril-induced damage to industry property business of a
5   specific reinsurance company. This concerns not only industry itself, but with the permanent rise of the flood insurance penetration, in addition to a concentration of values in areas prone to flood, the insurance and re-insurance industry is affected ever more by flood losses. However, flood rating has been badly neglected, despite the fact that often detailed information (address) on
10   the ceded risks is available. This is mainly owing to the fact that no efficient flood rating system is available. Ideally, such a system is made up of two components: first, it needs a street address geo-encoding to translate the addresses into a lat/lon and to make a lookup on the existing flood zones. Second, based on the lat/lon and flood zone information, a fully technical risk
15   rating (including event-based capacity calculation) can be performed.

The advantages of being able to do a correct technical risk rating for flood (e.g. on an Aggregated Loss Modelling (ALM) or Detailed Loss Modelling (DLM) basis) are plenty: (i) Better risk quantification: both components of an automated flood risk system will allow better estimatation of the risk exposure
20   of a detailed property schedule. It will be possible to reduce the number of "unexpected losses" e.g. to insurance, reinsurance or other industry. The improved risk quantification is enhanced by taking into account the TC-Flood correlation; (ii) Better structuring of flood-exposed programs or portfolios: since the contribution of every single risk to the expected losses can be quantified, it
25   is possible to determine site-dependent sub-limits or even to exclude certain sites from flood coverage; (iii) Essential improvements in flood risk assessment: It will be the first time in industry that a detailed and fully stochastic flood rating system is achieved. This can have a positive effect on the positioning of industry and/or insurance and re-insurance in the market, and can generate
30   new business opportunities; (iv) The availability of a detailed automated flood rating system will allow better qualification of property schedule data, e.g. in relation to identifying which policies have a flood coverage with the insurance industry; (v) Improved determination of capacity requirements: With a new

event set approach it will be possible to allocate expected losses consistently to a specific contract.

In the state of the art the US Geological Survey (USGS) National Elevation Dataset (NED) has been developed by merging the highest-
5 resolution, best-quality elevation data available across the United States into a seamless raster format. NED is the result of the maturation of the USGS effort to provide 1:24,000-scale Digital Elevation Model (DEM) data for the conterminous US Projection. NED has a resolution of one arc-second (approximately 30 meters) for the conterminous United States. In the NED
10 assembly process the elevation values are converted to decimal meters as a consistent unit of measure, North American Datum of 1983 (NAD83) is consistently used as horizontal datum, and all the data are recast in a geographic projection. NAD83 is based on the Geodetic Reference System of 1980 (GRS 80) ellipsoid that was developed to best-fit sea level over the entire
15 earth. In the state of the art there can also be found the National Landcover Dataset (NLCD). The National Land Cover Characterization project was created in 1995 to support the original Multi-Resolution Land Characterization (MRLC) initiative and fulfill the requirement to develop a nationally consistent land cover data set from MRLC data called National Land Cover Data 1992
20 (NLCD 92). This culminated in the September 2000 completion of land-cover mapping using a modified Anderson level II classification for the conterminous United States. The source data is the Landsat TM data for the years close to 1992. The National Land Cover Data (NLCD) is a 21-class land cover classification scheme applied consistently over the United States. In addition to
25 satellite data, scientists used a variety of supporting information including topography, census, agricultural statistics, soil characteristics, other land cover maps, and wetlands data to determine and label the land cover type at 30 meter resolution. The spatial resolution of the data is also in geographic projection, NAD 83. The relevant classes for flood assessment are the
30 following: A) Water: (11) Open Water, (12) Perennial Ice/Snow; B) Developed: (21) Low Intensity Residential (Discontinuous Urban) including areas with a mixture of constructed materials and vegetation, where constructed materials account for 30-80% of the cover and vegetation for 20-70%. These areas most commonly include single-family housing units and population densities lower

than in high intensity residential areas. (22) High Intensity Residential (Continuous Urban) including highly developed areas where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20% of the cover and constructed materials
5   for 80-100%. (23) Commercial/Industrial/Transportation (Industrial) including infrastructure (e.g. roads, railroads, etc.) and all highly developed areas not classified as High Intensity Residential. The growing need for land cover and other geospatial data within the federal government culminated in reforming the MRLC Consortium again in 2000 (MRLC 2001), with a second generation
10 national land-cover data set to be developed from the data called National Land Cover Data 2001 (NLCD 2001). The production of NLCD 2001 will be implemented in a phased approach using mapping regions developed by USGS. Full production development is anticipated to begin in 2002, with completion targeted for 2004. Unfortunately, this data will not be available
15 before 2005.

Further there is the National Hydrography Dataset (NHD) in the state of the art, which is a set of digital spatial data that contains information about surface water features such as lakes, ponds, streams, rivers, springs and wells. The National Hydrography Dataset (NHD) is a newly combined dataset that
20 provides hydrographic data for the United States on a hydrologic unit basis (8-digit number) . It is currently based on the content of the USGS 1:100,000-scale data, giving it accuracy consistent with those data. The horizontal positional accuracy is such that 90 percent of points are within 50 meters of their true position. The locations of points, lines, and the boundaries of areas
25 are encoded using geographic (longitude-latitude) coordinates. The horizontal datum is the North American Datum of 1983 (NAD83). In the state of the art the FloodMap from First American provides the most accurate, up-to-date flood hazard zones for risk assessment, insurance and re-insurance. This digital map database is based on Flood Rate Insurance Maps (FIRMs) prepared by the
30 Federal Emergency Management Agency to depict flood risks in support of the congressionally mandated National Flood Insurance Program (NFIP). The result of engineering flood insurance studies, FIRMs are used to implement floodplain management measures to reduce flood risks to communities and to perform flood insurance policy rating. These FIRMs depict Special Flood

Hazard Areas that are subject to inundation for both the 100-year flood
(national standard for flood insurance) and the 500-year flood zones. The First
American FloodMapSM database has been cleaned and corrected to reflect
information as shown on these paper FIRMs. National, State, Territory and
5   County First American Flood Hazard Certification currently has 3'100+ counties
of digital Flood Insurance Rate Maps. The county level coverage represents
over 99% of the U.S. population. FloodMap reflects all FEMA revisions (over
12000 a year). The entire database is refreshed quarterly to ensure accuracy,
currency and investment value. The dataset is provided in geographic
10   coordinates based on NAD83. In the dataset the coastal floodways and
floodplains (flood zone code "V*") are considered in a separate storm surge risk
evaluation. Finally, there is a data source for the USGS Daily Values
publication, the so-called USGS WATSTORE database in the state of the art. It
includes stream flow and related stream data with remarks (i.e. stream flow,
15   stage, water temp., lake level, reservoir storage, level below surface and more).
It includes 38,972 stations covering a record period of maximally from 1781 to
the present. It contains raw data, daily, monthly and exceedance statistics. The
datum for the coordinates of the gauging stations is also NAD83.

It should be pointed out that, besides the method according to the
20   invention, the present invention also relates to a system and a computer
program product for carrying out this method.

In particular the objects are achieved through the invention in that for
automated location-dependent recognition of flood risks, flood states being
measured and location-dependent probability values being determined, a
25   spatial high resolution grid is generated for a specific territory and flood risk
factors (P) are associated with the grid, the flood risk factors indicating the
average flood frequency and/or susceptibility to flooding within a grid cell, in
that river discharge parameters (T) are determined by measurements of
distributed gauging stations, the river discharge parameters comprising at least
30   values for return period and/or intensity of measured and/or stochastically
determined events, and in that the flood risk factors and the river discharge
values are linked by a correlation module to generate an event-specific
averaged probabilistic water depth value (H) for an event. Under spatial high

resolution a resolution with a cell size below 1km² is understood, in particular a cell size below 10'000m². One of the advantages of the invention is that a much more economic use of storage can be achieved, which also essentially influences the performance of the rating. For example, instead of storing water depths for each of tens of thousands of events or more, only one flood frequency map is stored at a highly detailed level (90m resolution). The event return periods are generated and stored on cell level. Both pieces of information are combined to calculate the water depth at a location for all the events. Additionally, a better structuring of flood-exposed programs or portfolios can be achieved. Since the contribution of every single risk to the expected losses can be quantified, it is possible to determine site dependent sub-limits or even to exclude certain sites from flood coverage. Further essential improvements in flood risk assessment can be provided: It will be the first time in industry that a detailed and fully stochastic flood rating system is achieved. This can have a positive effect on the positioning of industry and/or insurance and re-insurance in the market, and can generate new business opportunities. Another advantage of the invention is the availability of a detailed automated flood rating system, which will make it possible to require better quality property schedule data, e.g. in relation to identifying which policies have a flood coverage with the insurance industry. Finally, improved capacity allocation and determination can be done: With a new event set approach, it will be possible to allocate expected losses consistently to a specific contract. The correlation module can e.g. comprise at least five adaptable correlation parameters $x_1, x_2, ..., x_5$, whereas the adaptable parameters can e.g. be correlated by

$$H = \max\left(\frac{x_1P - x_2 + x_3 \ln(T)}{x_4P + x_5}, 0\right).$$

For flood cell zones along a coast located at different heights in meters above sea level, different correlation modules can e.g. be used. For example, for flood cell zones along a coast located lower than 10 m above sea level can be determined by a specific correlation module. The determination of the flood cells along a coast can e.g. be based additionally upon storm surge events. The determination of the flood cells along a coast can also comprise e.g. a Sea, Lake and Overland Surges from Hurricanes (SLOSH) method.

In an embodiment of the invention, a linking module comprises at least one adaptable event factor providing the spatial and/or temporal correlations for the discharge measurements of different gauging stations. This embodiment has inter alia the advantage that the distribution of return periods

5   between the single cells can show spatial and temporal correlations determined from discharge measurements of gauging stations, which can be taken into account by the at least one adaptable event factor.

In another embodiment of the invention, the river discharge parameters (T) are determined by measurements in a low spatial resolution in

10   relation to the grid of the flood risk factors. This embodiment has inter alia the advantage that the use of storage can further be economized, which also essentially influences the performance of the rating. For instance, instead of storing water depths for each of the tens of thousands of events or more, only one flood frequency map is stored at a highly detailed level (90m resolution).

15   The event return periods are generated and stored on cell level. Both pieces of information are combined to calculate the water depth at a location for all the events.

In still another embodiment according to the invention, the resolution of the grid cells is below 10'000m^2 for the diameter. It must be pointed out that,

20   in principle, it is possible to set the resolution to an arbitrary small cell size. However, the resolution is limited e.g. by the inherent errors of the parameters. This embodiment has, among other things, the advantage that the desired flood parameters can be properly determined by the system for a specific cell and/or site size.

25   In a further embodiment according to the invention, the flood risk factors (P) are derived based upon at least geomorphologic parameters. The geomorphologic parameters comprise e.g. horizontal distance and/or elevation difference to the next river and/or drainage area. This embodiment has inter alia the advantage that it comprises a method which is known in the state of the

30   art, and e.g. errors can be easily estimated. So the flood risk factors (P) can e.g. be derived by an interpolation module based upon a country-specific flood zone table depending on horizontal distance and/or elevation difference. For

the United States of America the country-specific flood zone table can comprise, for example, the First American 100-year flood zone table.

In an embodiment according to the invention, the vulnerability factors are determined based upon historical dataset of corresponding portfolios, and

5 a generalized insurance risk is automated derivable from the vulnerability factors. This embodiment has, among other things, the advantage that a fully automated system for determining the vulnerability factors of places and sites can be provided. This has not been possible up to now in the state of the art.

Additional features and advantages will become apparent to those

10 skilled in the art upon consideration of the following detailed description of illustrative embodiments exemplifying the best mode of carrying out the method as presently perceived.

The present disclosure will be described hereafter with reference to the attached drawings which are given as non-limiting examples only, in which:

15 Figure 1 and 2 show two diagrams which illustrates in the observation period 1 January 1997 - 31 December 2000; flood accounts for 55% of all natural peril-induced damage to property cooperate business (Figure 1) and for 44% of all natural peril-induced damage to industry business (Figure 2). The reference numeral A/E shows flood related losses, B/F storm

20 related losses, C/G earthquake/volcano related losses and D/H other losses.

Figure 3 shows a diagram illustrating a flood frequency map (p-map) based on extended FEMA 100-y flood zone. The interpolation depending on horizontal and vertical distance to next river to get other return periods. The reference numeral 1 is a 50-y flood zone, 2 is a 100-y flood zone, 3 is a 500-y

25 flood zone and 4 is a river.

Figure 4 shows a diagram illustrating an example of flood frequency map, where as the spatial resolution is 90 m grid cell size for the chosen map.

Figure 5 is a diagram which illustrates gauging stations with 25 years of records used for event set generation. This example shows used

30 gauging stations in North Caroline (US) where the determination is done based upon daily stream flow records.

Figure 6 is a diagram which illustrates the example event set with return periods per cell for the biggest event in North Carolina.

Figure 7 shows a diagram which illustrates the relation between flood frequency (P-value), water depth (H) and even set (return period T). The relation is plotted on Fig. 10 with the black dots indicating the values related to 100-year and 500-year flood zones and 100, respectively 500-year flood events.

Figure 8 shows a diagram which illustrates the same relationship as in Figure 7 but with different axes, representing the relationship between flood exposure, return period and water depth. It can be noted that for this example a flood event with a return period of 10 years, can only affect locations with P-values higher than 0.82 with water depths ranging up to 0.8 m. For a 100-year flood this range varies from 0.0 m (P<0. 54) up to 2.2 m (P=1).

Figure 9 shows a diagram illustrating the loss in relation to the frequency of the event for a random portfolio 6 of industry, residential and/or buildings etc. and a wind portfolio on the example of North Carolina (with vulnerabilities).

Figure 10 shows an elevation model of North Carolina (US) with the zones mentioned below. The elevation is given in meter above sea level (a.s.l.).

The overall operation, method and system of one embodiment of the subject method is discussed in the following. The system and method allow creation of a stochastic event set. One of the main benefit of the new approach is the highly economic use of storage, which directly influences the performance of the system and its operation. Instead of storing water depths for each of tens of thousands of events, only one or very few flood frequency maps have to be stored at a highly detailed level (90m resolution). The event return periods are generated and stored on the desired cell level. Both pieces of information are combined to calculate the water depth at a location for all the events. In this embodiment variant, a spatial high resolution grid is generated for a specific territory, and flood risk factors (P) are associated with the grid, the flood risk factors indicating the average flood frequency and/or susceptibility to flooding within a grid cell. As an example of the flood risk factors, i.e. a flood frequency map, e.g. the state of North Carolina (NC) / United States (US) can

be chosen as prototype territory. North Carolina has a surface of 140'000 km^2 (for comparison mainland United Kingdom has 220 000 km^2) and 6.8 Mio citizens. The extent of North Carolina is 850 km in west-east direction and 305 km in north-south direction. The highest point culminates on Mount Mitchell at

5 2037 meters above sea level. The Atlantic coast is 484 km long. The topography is divided into three distinct regions: the Atlantic coast plain (2/3) up to 80 km into the inner land (elevation < 90 m a.s.l.), the Piedmont Plateau (elevation 90-460ma.s.l.) and the Appalachian (elevation > 460 meters above sea level). Figure 10 shows an elevation model of NC with the mentioned

10 zones. Between Cape Hatteras and Cape Fear some regions are often affected by hurricanes. For the flood frequency map (or P-map) the grid can e.g. consist of values between 0 (never flooded) and 1 (always flooded) indicating the susceptibility to flooding. In this example the values can e.g. be derived from the First American 100-year flood zones, the digital elevation model and the

15 river network. As mentioned, the flood frequency map, i.e. the flood risk values associated with the grid, can e.g. consist of values between 0 (never flooded) and 1 (always flooded) indicating the susceptibility to flooding of each location (latitude, longitude). The values of the flood risk factors (P) between 0 and 1 can be related directly to flood frequency, for example P=0.58 stands for the

20 100-year flood zone. Of course, other flood zones could be chosen as e.g. flood zones with a certain other return period (50-, 100-, 250-, 500-years). The flood zones can be determined based on geomorphologic parameters such as the horizontal distance and elevation difference to the next river and/or the drainage area. The data in this example were e.g. validated with FEMA data

25 from the USA and proofed good results in several countries (CZE, UK, SVK, BEL). In the example of the embodiment, the First American 100-year flood zones are used to interpolate by an interpolation module depending on the horizontal distance and elevation difference of the cell. The interpolation module can be achieved through hardware and/or software. An additional

30 advantage of taking the 100-year flood zones for calibration is that flood protection measures will be automatically taken into account. The processing steps can comprise e.g. the following steps: (i) Prepare National Elevation Dataset: Merge, project and fill grid; (ii) Prepare First American FloodMapSM Dataset: Select zones, project, clean and expand grid by 600 m (the size of the

35 buffer will be adapted depending on the regions), which results in a extended or buffered 100-year flood zone. (iii) Prepare National Hydrography Dataset: Select rivers, project grid. (All the datasets contain the elevation data and can

e.g. be saved to a storage module); (iv) Generation of p-value map: With a appropriate processing module the input files are then processed to result in a grid with the extend of the buffered flood zones with p-values. a) Nearest neighbor lookup of buffer grid points on river network: Determination of
5 horizontal distance and elevation difference. b) Nearest neighbor lookup of grid point at 100-year flood zone border on river network: Determination of horizontal distance and elevation difference. c) Determine calibration parameter with MARS formula. d) Smoothing of calibration parameter. e) determine p-value and e.g. save them into to storage module. (v) Post-
10 processing: Aggregate, clean and reproject grid to geographic coordinates.

The quality of the p-value map can e.g. be checked by a test portfolio with known locations. These locations can then be checked with both grids (First American flood zone and p-value map). The results for this example are illustrated in Table 1, where all locations lying within the First American
15 100-year flood zones are taken and checked against the p-value map. As can be seen, 73% of all checked locations in North Caroline (NC) are also found in the 100-year flood zone of the p-value map, and 97% are in 500-year flood zones of the p-value map. It is important to note that the flood zone along the coast can often include storm surge zones, and it is clear that in these areas
20 the presented method is not well adapted (no rivers available). Therefore a second check can be made, taking only the locations above 10 meters above sea level, and in that case 92% of the locations from the p-value map fall into the 100-year flood zone.

Table 1. Comparison of locations lying in First American 100-year
25 flood zone with those from p-value map.

Flood zone	All locations within First American 100-year flood zone	Locations within First American 100-year flood zone (>10 m. a.s.l.)
50-year	73 (47%)	39 (74%)
100-year	112 (73%)	49 (92%)
250-year	146 (95%)	52 (98%)

500-year	149 (97%)	53 (100%)

Over the whole of NC, the area affected by a 100-year flood
determined by the system from the p-value map underestimates the First
American flooded area by only 2.6%. Comparing the two datasets, it can be
5 seen for this example that in the flat coastal region the flooded area is rather
underestimated, which is due to the fact that storm surge is not taken into
account yet. A slight overestimation exists in the central part of NC, but this is
not significant. The final p-value map has in this embodiment example a cell
size of 90 m, which is precise enough taking into account the precision of the
10 geo-encoding. By that way, the total amount of data can be divided by a factor
9. The total size of the p-value map (p>0.2) for NC includes 5.2 mn cells.
Taking the whole USA, this would result in 360 Mio cells, assuming that the
same percentage of area is flooded.

Further river discharge parameters (T) are determined by
15 measurments by distributed gauging stations, the river discharge parameters
comprising at least values for return period and/or intensity of measured
events. For this example the river discharge parameters (T) are also called
event set T-table. The T-table comprises for the example the return periods of
1183 flood events affecting the 1082 cell zones of North Carolina. A
20 probabilistic event set is derived from the statistics of 74 river discharge
gauging stations. Again, the event set specifies the return period or intensity of
one event in a given cell of the grid. The distribution of return periods between
the cells can take into account the spatial and temporal correlations determined
from discharge measurements of gauging stations covering a range of 25 years
25 from 1977-2002. Totally, 74 stations fulfilled this requirement for the example of
North Carolina. For the whole USA, approximately 3000 stations can be used.
It is clear that not only head catchment gauging stations can be used for the
system, but also stations at main rivers. It has to be noted that only few stations
were available in the coastal area as can be seen on Figure 5.

30 The reason for the selection of return period as a measure of
intensity lies mainly in its relative weak variation along the river network, i. e.
the return period between adjacent cells of the grid on a river varies "smoothly".

Figure 6 shows the distribution of return periods on cell resolution for the biggest event in the North Carolina event set. The chosen definition of events through return periods further allows real events to be easily included by the means of extreme value analysis of the time series, for example the 1993 flood.

5   Real events also provide the possibility, on the one hand, of a direct comparison with possible loss data and, on the other hand, a plausibility check of the probabilistic events. Finally, post-event analysis could be made by downloading the newest discharge measurements and analyzing them with the past time series.

10   The flood risk factors and the river discharge values are linked by a correlation module to generate an event-specific averaged probabilistic water depth value (H) for an event, which is in this example the desired location-dependent flood probability value. The correlation module can e.g. be achieved through hardware and/or software. To link the flood frequency map (p-value

15   map) and the event set (return period T) with the hazard, i.e. water depth H, a relationship indicating a mean average water depth as a function of these two parameters is necessary. To determine such a relationship e.g. an analysis based on the probabilistic flood event set of a known territory can be done. In this example, a probabilistic flood event set of the UK was chosen. The chosen

20   event set consists of 973 flood maps indicating the water depth at each flooded cell with a resolution of 50 m. For the analysis, the unprotected event set was used. In order to perform the analysis, the flood frequency P-value of each cell had to be known. Therefore, the P-map determined by the system was taken as a mask. Specifically, this means that for each event or flood footprint, the water

25   depths of all cells with a certain P-value were collected. This collection allows e.g. for a classification into 8 water depth classes (0-4.0 m) and 16 p-value classes 0.2-0.9. If the number of occurrences in each class is divided by the total sum of observations, the relative frequency f_i can be calculated as

$$f_i = \frac{\text{Number of occurrence s in class } i}{\sum_i \text{Number of occurrence s in class } i}$$

30   and the corresponding return period is

$$T_i = \frac{1}{f_i}.$$

This method can also be explained by the fact that, with a high number of events and flooded cells, this frequency distribution of water depths and P-values becomes an intrinsic function which is independent of the number
5 of events. Or, in other words, if you add 10 additional events, the relative frequency will not change, and still represents the occurrence frequency.

To give an analytical expression for the relationship, the values of the example were fitted to the following function

10 $$T = \exp(8.9 + 0.5 \cdot H - 8.0 \cdot P + 1.2 \cdot H \cdot P)$$

or

$$H = \max\left(\frac{8 \cdot P - 8.9 + \log(T)}{1.2 \cdot P + 0.5}, 0\right) \text{ for } T > 2.5$$

The function is plotted on Figure 7 with the black dots indicating the
15 values related to 100-year and 500-year flood zones and 100, resp. 500-year flood events. The P-values for the 100-year (P≥0.58) and 500-year flood zone (P≥0.35) were given by the calibration of the MARS model to the FEMA flood zones of several regions in the USA. Taking the P-H-T relationship, these P-values with the corresponding return period T result in water depths of 0.3 m,
20 resp. 0.1m. In Figure 8 the same relationship is presented with different axis. It can be noted that, for example, a flood event with a return period of 10 years can only affect locations with P-values higher than 0.82, with water depths ranging up to 0.8 m. For a 100-year flood, this range varies from 0.0 m (P<0. 54) up to 2.2 m (P=1). To get additional information for this example about the
25 mentioned relationship, a questionnaire was used where all flood people from Zurich, Munich and Armonk gave their best estimate of such a relationship between flood frequency, event return period and water depth. The results of this "expert view" are compared with the analytical relationship. The comparison shows that the analytical relationship is slightly more conservative
30 than the estimates indicating that during the calibration work some smaller modifications to the relationship could be done.

It is clear that the system and method also allow the values to be verified and adapted for flood zones other than 100-year and 500-year. The proposed P-values can be e.g. as follows: (i) 50-year flood zone: P=0.69 (resulting water depth with 50-year flood event H=0.4 m); (ii) 250-year flood zone: P=0.45 (resulting water depth with 250-year flood event H=0.2 m); (iii) 25-year food zone: P=0.82 (resulting in water depth with 25-year flood event H=0.6 m). Based on the return periods of all events (in every second cell) and on the complete flood frequency map, the water depth distribution can be determined. In the example given here in 54% of all cases the water depth is below 50 cm.

As shown above for the example, a rather large area of North Carolina lies below 10 meters above sea level, and is potentially affected by storm surge events. The system and method described above is well adapted for river floods inland located higher than 10 meters above sea level, but along the coast the flood zones also include the risk of storm surge, and for this area it can be reasonable to use a specific model. Such differentiations can easily be included in the same way, and form part of the invention. For example, storm surge events can be included in the system and/or method. Another possibility would be to use the SLOSH (Sea, Lake and Overland Surges from Hurricanes) method, which is a method used by the National Hurricane Center (NHC) to estimate storm surge heights resulting from historical, hypothetical, or predicted hurricanes. The second model takes into account pressure, size, forward speed, track and winds, which could be obtained from TCart. Independently of the method and/or system used, some kind of storm surge frequency map should be developed in order to be consistent with the river flood event set. The storm surge event set would then also consist of return periods, where the events are "linked" to the corresponding TC events. For storm surge different P-H-T relationships as well as vulnerability curves must be defined. The relation between river floods and TCs is less evident. However also the correlations between the river floods and TCs can be considered. Here, it can be reasonable to perform a matching between the TC rainfall maps and the river flood return periods.

Although the present disclosure has been described with reference to particular means, materials and embodiments, one skilled in the art can

easily ascertain from the foregoing description the essential characteristics of the present disclosure, while various changes and modifications may be made to adapt the various uses and characteristics without departing from the spirit and scope of the present invention as set forth in the following claims.

Claims

1. Method for automated location dependent recognition of flood risks, flood states being measured and location-dependent flood probability values being determined, characterized

5   in that a spatial high resolution grid is generated for a specific territory and flood risk factors (P) are associated with the grid, the flood risk factors indicating the average flood frequency and/or susceptibility to flooding within a grid cell,

in that river discharge parameters (T) are determined by
10   measurments of distributed gauging stations, the river discharge parameters comprising at least values for return period and/or intensity of measured and/or stochastically generated events, and

in that the flood risk factors and the river discharge values are linked by a correlation module to generate an event-specific averaged probabilistic
15   water depth value (H) for an event.

2. Method according to claim 1, characterized in that a linking module comprises at least one adaptable event factor providing the spatial and/or temporal correlations for the discharge measurements of different gauging stations.

20   3. Method according to one of the claims 1 or 2, characterized in that river water level parameters are measured by the gauging stations, based upon which river water level parameters the river discharge parameters are determined.

4. Method according to one of the claims 1 to 3, characterized in that
25   the river discharge parameters (T) are measured and/or determined in a low spatial resolution in relation to the grid of the flood risk factors.

5. Method according to one of the claims 1 to 4, characterized in that the river discharge parameters (T) are measured and/or determined in a high temporal resolution.

18

6. Method according to one of the claims 1 to 5, characterized in that the resolution of the grid is given by cell sizes below 10'000m^2.

7. Method according to one of the claims 1 to 6, characterized in that the flood risk factors (P) are derived based upon at least geomorphologic parameters.

8. Method according to claim 7, characterized in that the geomorphologic parameters comprise horizontal distance and/or elevation difference to the next river.

9. Method according to on of the claims 7 or 8, characterized in that the geomorphologic parameters comprise horizontal distance and/or elevation difference to the next drainage area.

10. Method according to one of the claims 1 to 9, characterized in that the flood risk factors (P) are derived by an interpolation module based upon a country-specific flood zone table depending on horizontal distance and/or elevation difference.

11. Method according to claim 10, characterized in that the country specific flood zone table comprises the First American 100-year flood zone table.

12. Method according to one of the claims 1 to 11, characterized in that the correlation module comprises at least four adaptable correlation parameters x_1, x_2, ..., x_5, whereas the adaptable parameters are correlated by

$$H = \max\left(\frac{x_1 P - x_2 + x_3 \ln(T)}{x_4 P + x_5}, 0\right).$$

13. Method according to one of the claims 1 to 12, characterized in that vulnerability factors are determined based upon historical dataset of corresponding portfolios and a generalized insurance risk is automated derivable from the vulnerability factors.

14. Method according to one of the claims 1 to 13, characterized different correlation modules are used for flood cell zones along a cost located different height m a. s. l..

15. Method according to claim to 14, characterized in that flood cell zones along a cost located lower than 10 m a. s. l. are determined by a specific correlation module.

16. Method according to one of the claims 14 or 15, characterized in that the determination of the flood cells along a cost are additionally based upon storm surge events.

17. Method according to one of the claims 14 to 16, characterized in that the determination of the flood cells along a cost additionally comprises a Sea, Lake and Overland Surges from Hurricanes (SLOSH) method.

18. System for automated location-dependent recognition of flood risks, flood states being measured and location-dependent flood probability values being determined, characterized

in that a spatial high resolution grid is generable for a specific territory and flood risk factors (P) are associated with the grid, the flood risk factors indicating the averaged flood frequency and/or susceptibility to flooding within a grid cell,

in that river discharge parameters (T) are measurable by distributed gauging stations, the river discharge parameters comprising at least values for return period and/or intensity of measured events, and

in that the flood risk factors and the river discharge values are linkable by a correlation-module to generate an event-specific averaged probabilistic water depth value (H) for an event.

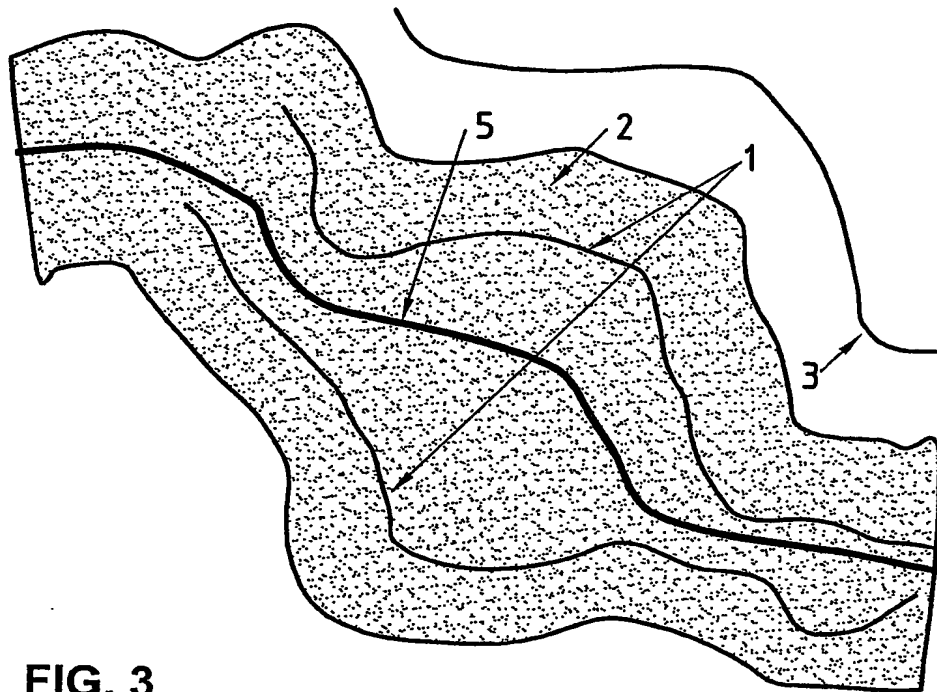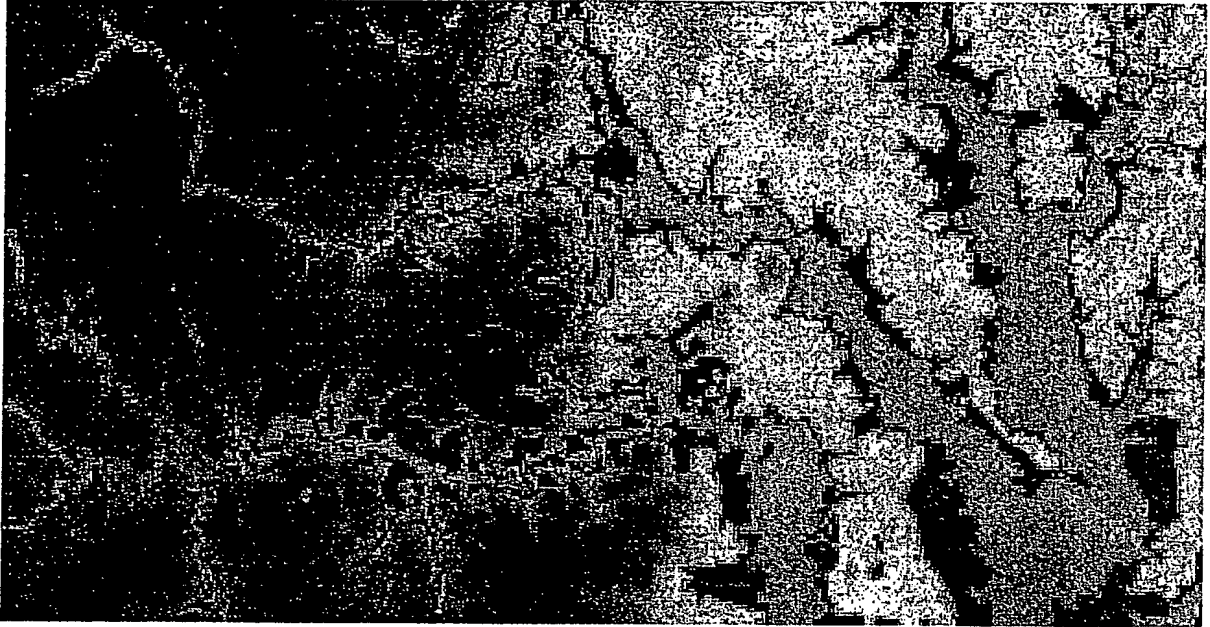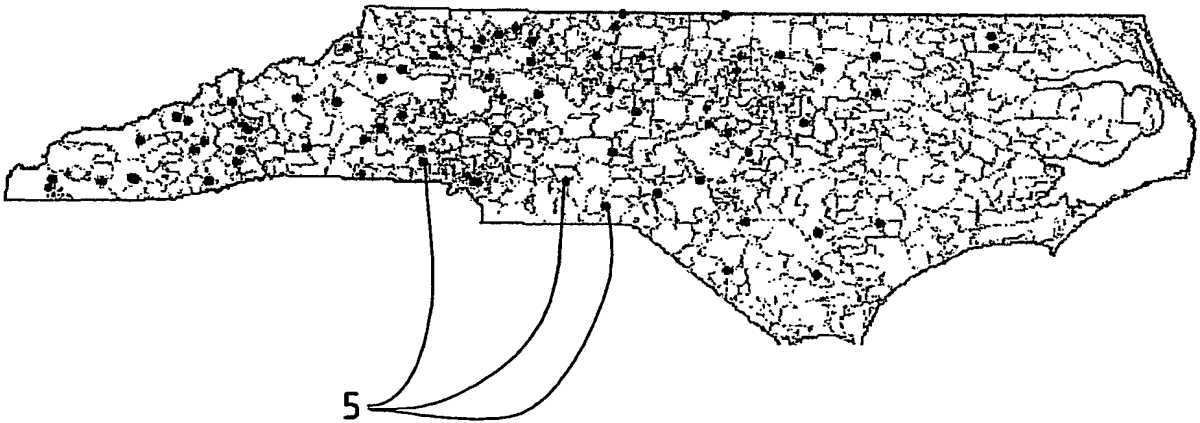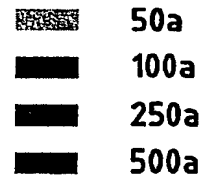19. A computer program product which is able to be loaded in the internal memory of a digital computer and comprises software code sections with which the steps according to one of the claims 1 to 17 are able to be carried out when the product runs on a computer.

Abstract

The invention relates to a method for automated location-dependent recognition of flood risks, in which a spatial high resolution grid is generated for a specific territory, and flood risk factors (P) indicating the averaged flood
5   frequency and/or susceptibility to flooding within a grid cell are associated with the grid, in which river discharge parameters (T) are measured by distributed gauging stations, whereas the river discharge parameters comprise at least values for return period and/or intensity of measured events, and in which the flood risk factors and the river discharge values are linked by a correlation-
10   module to generate an event specific averaged probabilistic water depth value (H) for an event.

(Figure 7)

15

FIG. 1

☑ 44% A
☒ 29% B
☐ 12% C
☐ 15% D

FIG. 2

☑ 55% E
☒ 16% F
☐ 15% G
☐ 14% H

FIG. 3

FIG. 4

▨	50a
▬	100a
▬	250a
▬	500a

5

FIG. 5

Event return period

- < 2.5
- 2.5 - 10
- 10 - 25
- 25 - 50
- 50 - 100
- 100 - 250
- 250 - 500
- 500 - 1000
- > 1000

FIG. 6

T [t]

1000

500

250

100

50

25

10

5

H [m]

p

FIG. 7

FIG. 8

FIG.9

Elevation [ma.s.l]

-20 - 0
0 - 90
90 - 300
300 - 460
460 - 700
700 - 900
900 - 1100
1100 - 1300
1300 - 2038

100   0   100   200 [Km]
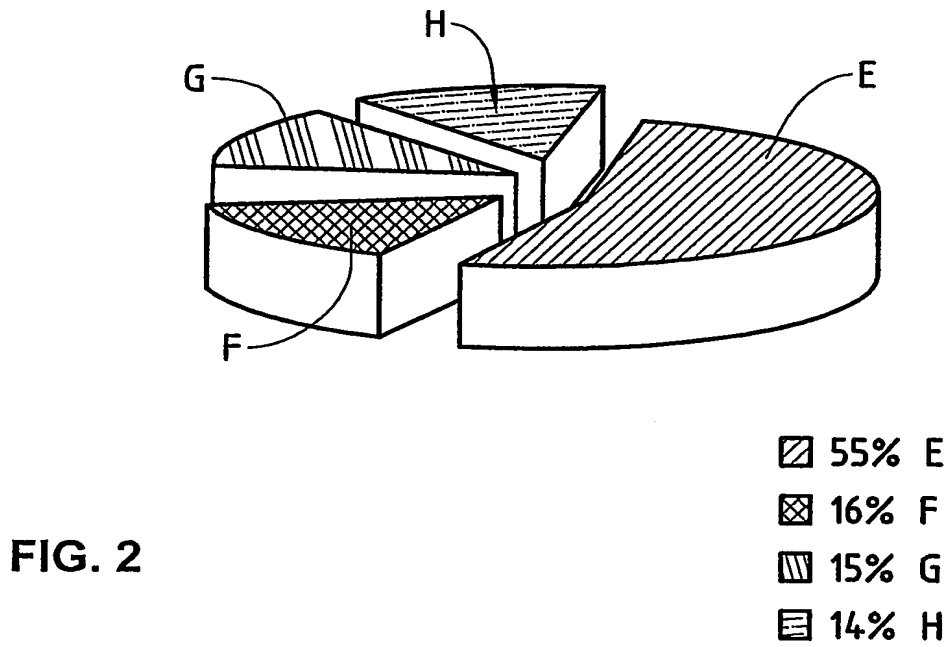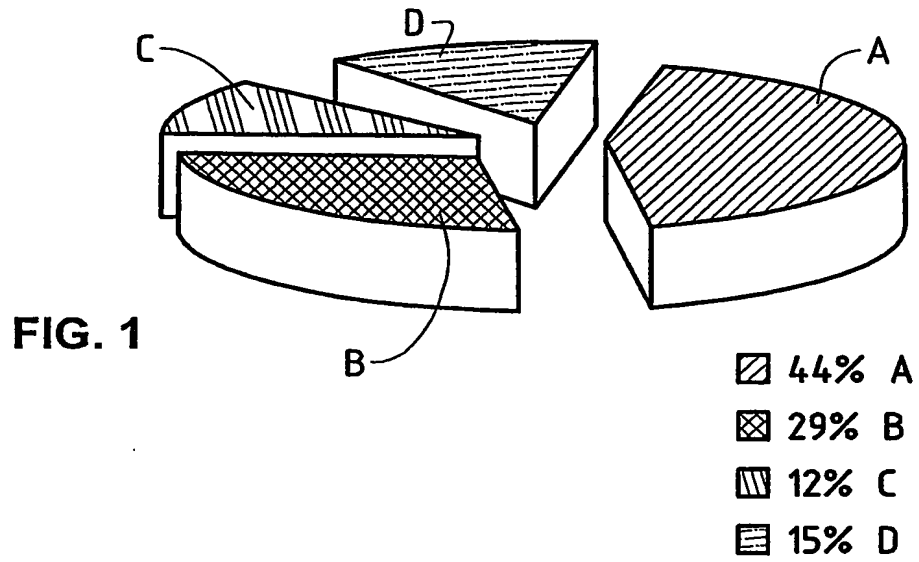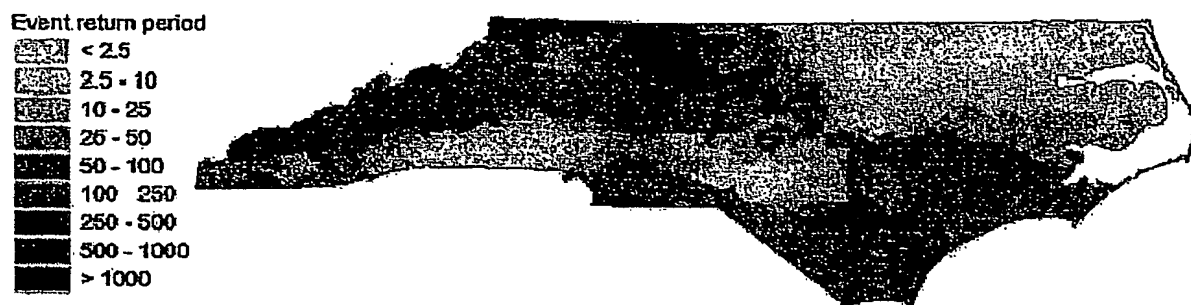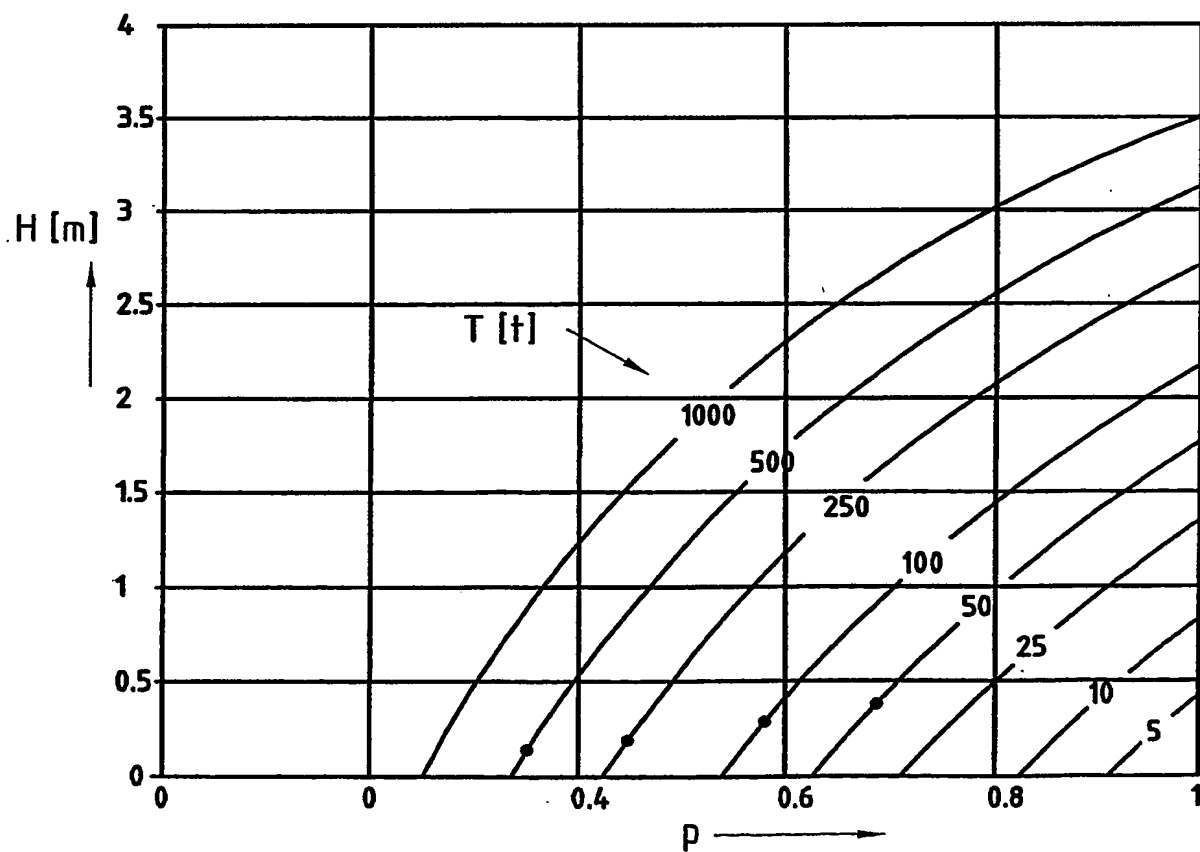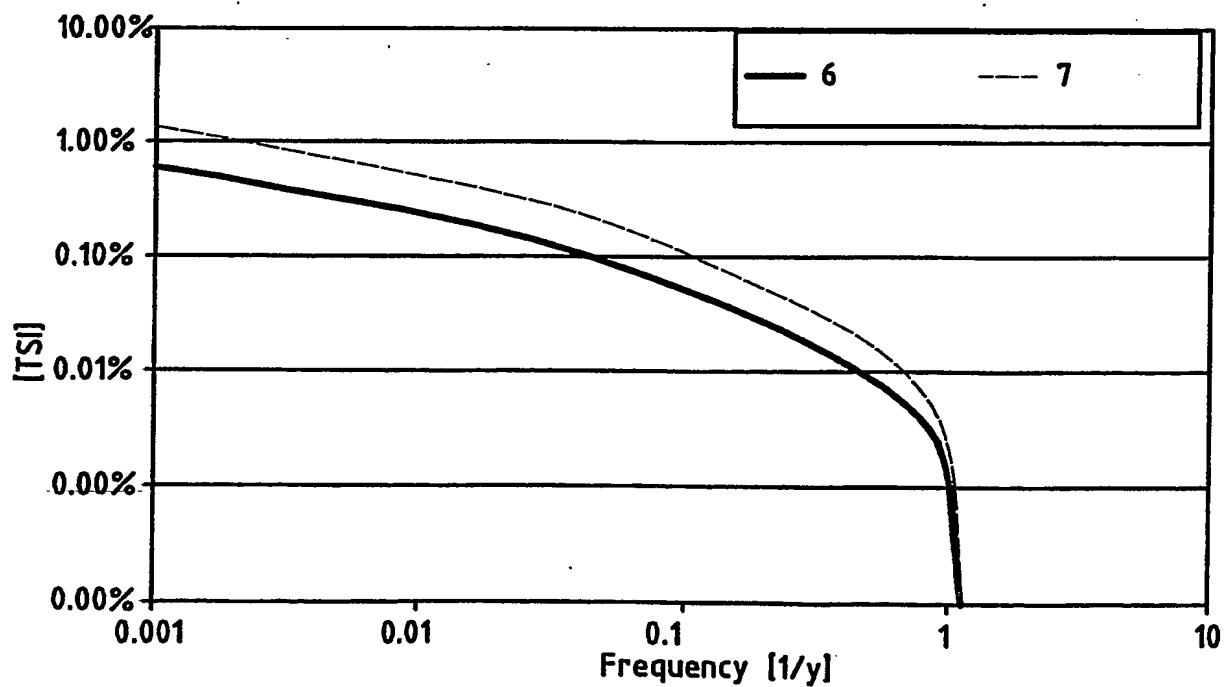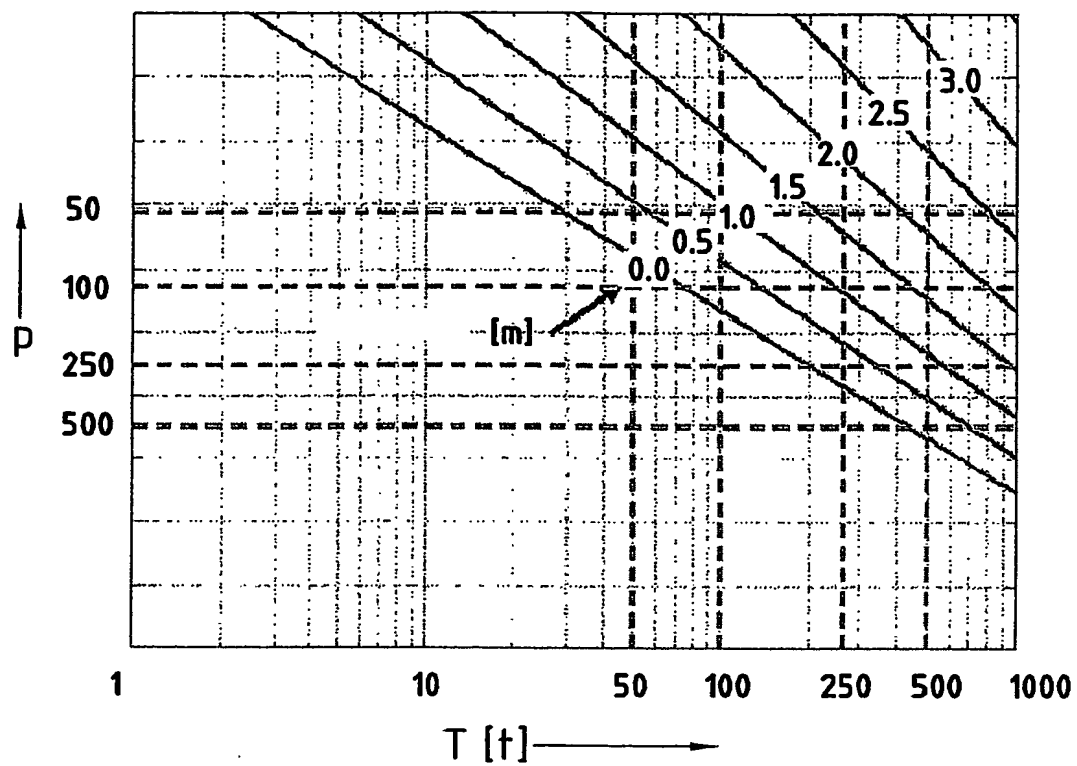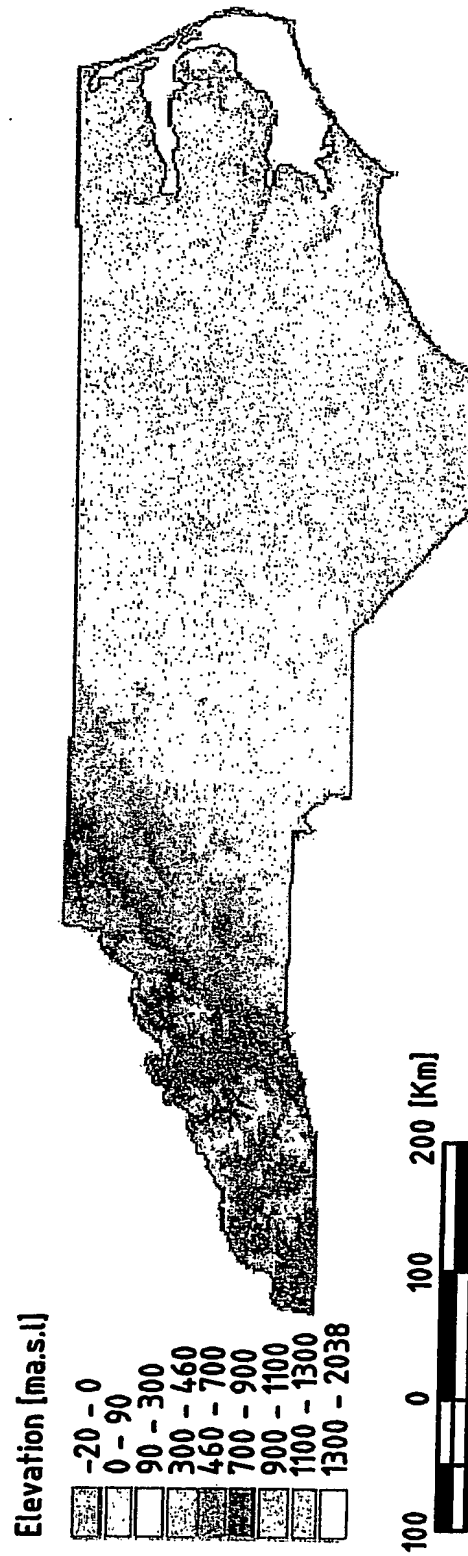
FIG. 10

Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/CH05/000365

International filing date: 30 June 2005 (30.06.2005)

Document type: Certified copy of priority document

Document details: Country/Office: EP
Number: PCT/EP2004/051317
Filing date: 30 June 2004 (30.06.2004)

Date of receipt at the International Bureau: 05 September 2005 (05.09.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

World Intellectual Property Organization (WIPO) - Geneva, Switzerland
Organisation Mondiale de la Propriété Intellectuelle (OMPI) - Genève, Suisse